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Review Article

The Overlap between Sustainable Development and Genetics Laboratorial Techniques-Narrative Review

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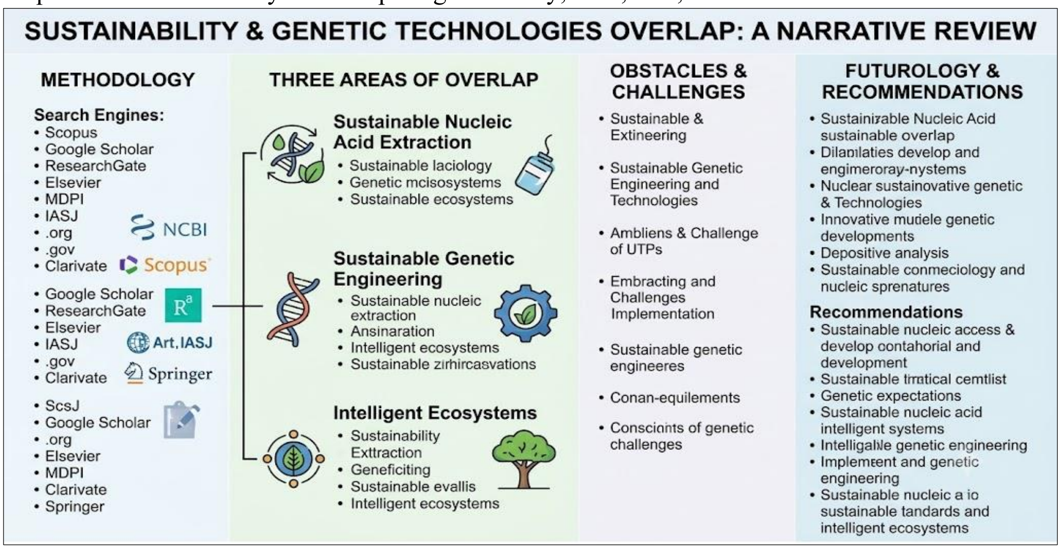
Abstract: Sustainability includes the use of available resources at a minimal level. The current review aims to reveal the overlap between sustainability and genetic technologies, as well as to identify obstacles and proposed futurology. A narrative methodology was used, where keywords were searched in (Ncbi, Scopus, ResearchGate, Google Scholar, Elsevier, MDPI, iasj, .org, .gov, Clarivate, Springer), followed by summarizing, and analyzing the most important conclusions, of the studies, and organizing their topics according to their logical diversity. A strong overlap observed between sustainability and genetic techniques. It includes three areas: the first is a sustainable extraction of nucleic acids. The second is sustainable genetic engineering techniques. The third is computational modeling, automation, robotics, and big data, plan improvement, and providing sustainable intelligent ecosystems. There are obstacles including high cost, off-target activity, immune responses, difficulty in accurately describing large genetic repeats, harmful environmental consequences, and fear of genetic engineering applications. Futurology contains that disease monitoring, and diagnosis will be facilitated computationally and robotically, and that the efficiency, productivity, and reliability will increase, while their time, damage, and costs will decrease. Conduct future studies recommended uncovering the overlap of each field of genetic techniques with sustainability and comparing efficiency, time, cost, and harm.



Graphical Abstract

Keywords: Sustainable Development, Genetic Technologies, Molecular Technologies, Genetic Engineering Techniques, Green Genetic Technologies.

1. INTRODUCTION

Scientists have tried to scrutinize scientific accumulation and its applications, and to uncover the best conditions for its procedures for a long time. These efforts encouraged discussions among scientists and experts to find common working spaces, thereby identifying specific topics related to current sustainability to existing problems [1]. The successive efforts to develop sustainability science studies are important for addressing the successive problems associated with the interactions between humans and their environment. Such future research requires setting certain priorities to advance this scientific field [2]. Sustainability enables us to address pressing environmental issues such as climate change and pollution. Its applications mitigate the effects of climate change by reducing waste and supporting recycling, implementing sustainable supply chain practices, using renewable energy, and employing alternative climate change solutions in daily practices [3].

Sustainability is based on a simple principle: our needs to stay alive and prosperous depend on our natural environment. This requires creating conditions in which humans live in harmony with their environment and preserve it, while allowing the needs of society, the economy, and others to be met for both current and future generations. This thinking has strengthened the ambitions of those interested in sustainability and their participation in sharing best practices to achieve the greatest benefit for the environment, economy, and society [4].

Scientific studies in this field address physical interactions and problems with ethical and literary aspects. These activities raise important topics for finding the best ways to manage those studies [1]. Sustainability involves obtaining materials from non-traditional sources, increasing resources, recycling, and reducing the circulation of hazardous materials. It intersects with all financial, administrative, agricultural, and engineering fields, and supports institutional prosperity. Likewise, the number of patents in the field of sustainability has increased [5].

The sustainable development goals are achieved through conducting studies in renewable energy applications, smart grid developments, and artificial intelligence. Therefore, technology can be utilized in research across the edges of various sciences and collaborative efforts of the parties concerned. This requires continuous research efforts. There is also a need to integrate work between technology and sustainability [6]. A study by Mohania, *et al.*, (2025) [7], indicated that technological innovations enhance the formation of sustainable development, through supporting green innovations and changing environmental tax regulations. This study linked technology, sustainability, and economic policy, and focused on how technological advancement drives environmentally friendly solutions.

The current review assumes that integrating the concept and applications of sustainability with the technologies used in genetics labs leads to improving those technologies in terms of reducing effort, time, and money needed, ensures a higher level of lab safety and security, opens important future prospects, and reveals obstacles that deserve attention.

Depending on adoption of sustainability, and as a result of continuous encouragement from relevant authorities, and due to the overlap of the concept of sustainability with various disciplines, including the different branches of life sciences, which has emerged in the studies presented above, the current review was conducted to fill the gap represented by the nature of the interaction between the concept of sustainability and the technologies used in genetics laboratories. Therefore, the current review aimed to reveal the interaction between sustainable development and the technologies used in genetics laboratories and their sub-disciplines, especially molecular biology and genetic engineering, the role of sustainable development in developing these technologies, and to identify obstacles and future perspectives in this field, through collecting the largest possible number of studies in this area, analyzing them, and providing the best conceptualization for specialists and researchers about this relationship.

2. METHODOLOGY

The narrative style used in this review; keywords related to the title searched on various scientific websites, including (NCBI, Scopus, ResearchGate, Google Scholar, Elsevier, MDPI, IASJ, .org, .gov, Clarivate, Springer), then the most important conclusions, ideas, and recommendations of collected studies summarized, and their topics were organized according to their logical variety. Their ideas were also analyzed and critiqued to highlight their orientations, obstacles, and future visions. The main ideas of these studies concluded in brief notes. Suggestions and recommendations are also made. The steps of the current study are shown in the form (1) below:

3. THE CONCEPT OF SUSTAINABLE DEVELOPMENT

Sustainability achieves three interrelated benefits: environmental protection, economic growth, and social justice. It addresses pollution, preserves ecosystems and resources, and generally improves the quality of life. Sustainability means meeting current needs without depleting the resources necessary for future generations, ensuring the long-term survival of humans and their environment. This requires use of green technology, disciplined business practices, and effective plans. Various roles identified in the field of sustainability, such as sustainability specialist, analyst, manager, and environmental consultant [8].

Sustainability also contributes to the development of resources in addition to restricting their misuse [9].

It is necessary to improve the environmental performance of technological activities, to develop new green applications. Digitization leads to quantitative measurement, reduces complexity and waste, and supports information storage and computing capabilities through the application. The performance of institutions improves with the intervention of artificial intelligence, machine learning, robotic automation, cloud computing, smart sensing, and network-connected machines. Sustainability also intervenes in industrial processes to document and store complex processes to create a sustainable environment. Sustainability also aims to save energy and achieve the best quality using the latest technologies and to create a zero-emission ecosystem, which necessitates recycling waste on-site [10].

4. Genetic Techniques

Genetic techniques have significant developments in various fields because of the increasing demand for rapid and reliable diagnosis in different areas, such as disease diagnosis, food quality, and environmental studies. Many modern applications attempt to integrate nucleic acid extraction and detection into simplified procedures with faster performance and greater reliability [11].

Many researchers summarized various techniques used in genetics applications, which include genetic modification, cloning, and disease analysis like direct-to-consumer (DTC) genetic testing [12]. These include genomic DNA isolation, detection of a specific sequence by polymerase chain reaction (PCR), bacterial enzymatic digestion and DNA recombination, and gel electrophoresis [13].

As well as the Human Genome Project and the sequencing of the organism's complete genome, digestion of nuclei by restriction, transcription activator-like effector nucleases (TALENs), the clustered regularly interspaced short palindromic repeats (CRISPR-Cas), X-ray crystallography, guanine-rich regions, and long single-stranded DNA primers [14]. Microarrays and genome-wide association [15].

Other techniques are double-strand unwinding, chromatography, and automated extraction. Also contain Agilent Bioanalyzer, and spectroscopy (NanoDrop). Others are automated single-cell DNA analysis, mapping and DNA analysis and staining mRNA sequences (Northern blotting), and the ribonuclease protection assay. Genetic probes, synthetic DNA assembly, DNA printing, Radiolabeling using phosphorus-32 or sulfur-35 and tritium, final classification of DNA molecules, Reverse transcription PCR (RT-PCR). Automation and improvements in qPCR (Agilent bioanalyzer, and alternative amplification). Enzymatic (Sanger), and chemical (Maxam-Gilbert) and automated sequencing, next-generation sequencing, RNA sequencing, chromatin immunoprecipitation sequencing, exome sequencing, genomics, and sequencing with advanced software, the 454 platform, shotgun approach, and sequencing by oligonucleotide. Single-molecule real-time sequencing, methylation, gene expression, SNP arrays, and the HapMap project [16].

5. Applications For Genetic Technologies

The aforementioned genetic technologies are used in various applications; for example, it used to detect and analyze genetic sequences, mutations, genetic maps, and gene expression of nucleic acid, and to diagnose metabolic, genetic, and microbial diseases [12-17]. These applications are shown in the table (1) below:

6. SUSTAINABILITY AND GENETIC TECHNOLOGIES

Many researchers have explored the overlap between the concept of sustainability and genetic technologies, as their research lines included areas of sustainability and nucleic acid extraction, sustainability and genetic engineering, sustainability and genetic production, sustainability and green genetic technologies, and sustainability and environmental genetics.

6.1. Overlap between Sustainability and Nucleic Acid Extraction

One paper reveals the overlap between nucleic acid extraction techniques and sustainability, by examining the storage conditions of viral samples and the composition of the lysis solution. It found that do6.uble-stranded DNA viruses may be less affected by the ribonucleases present in VTM containing serum. Also, repeated freeze-thaw cycles cause a failure to maintain the cold chain, then a negative impact on extraction, and that RNase-free VTM and VTM containing cryoprotective substances (glycerol) provide similar effectiveness in preserving samples over repeated freeze-thaw cycles. This result is very useful for areas that suffer from a lack of resources and inadequate sample storage sites. It also revealed that many 'green' surfactants, such as Tergitol 15-S-7, Tergitol 15-S-9, and Tween-20, can be used as alternatives to Triton X-100. Moreover, incorporating surfactants in LB formulations was ineffective, as the presence of ethanol and GITC is sufficient to lyse cells without the surfactant, with an insignificant harmful effect on Ct when the surfactant is absent. RNA extraction was also affected by the presence of RNases. The extraction is very effective in capturing RNA. Likewise, EDTA, GITC, and DTT present in the lysis solution inhibit RNases. This study recommended using VTM without serum to store ssRNA virus samples and maintain the cold chain. It also recommended removing surfactants from LB formulations and adding low concentrations of nuclease inhibitors, such as ETDA, GITC, and DTT, to sample solutions. Adherence to these suggestions can significantly reduce the environmental impacts of RNA extraction by inactivating nucleases before cell lysis to ensure near-quantitative RNA extraction. These data provide insight into the need for advanced extraction techniques and offer suggestions for preserving viral RNA samples and improving the sustainability of RNA extraction. Implementing such recommendations may increase RNA sample quality, improve detection using qRT-PCR, and increase diagnostic sensitivity, while reducing the environmental impact of the RNA extraction process [18].

Another paper studied genetic modifications related to aspects of sustainability. It addressed biodiversity and environmental impact, and applications of genetically modified crops. It indicated that using complementary new breeding techniques provides solutions for food security and climate change, with the possibility of introducing a wider range of more desirable food products. Supporters of genetically modified organisms advocate for adequate studies to market crop production. Genome editing and CRISPR-Cas9 technology are important techniques capable of impacting science, agricultural production, and society. Genetically modified organisms increase the quality of medical care and food abundance, enhance environmental quality, combat poverty and diseases, strengthen the economy, and reduce damage [19].

There are forward recommendations for sustainable ancient DNA research. A recent article confirmed that true collaboration requires time and sustainable research methods. Article suggested applying a 'local-global' plan to aDNA research in certain countries. Global systems should be context-sensitive and based on the interaction between local and global processes. In aDNA research, applying global principles of sustainability and justice while maintaining awareness of historical harm caused by exploitation by researchers from other countries is required. Locally, researchers in ancient DNA should be aware of the implications of their research. There is also the necessity of involving the local community by recognizing this work or funding it as an essential part of the research process. Despite the time and effort required, such commitments strengthen the formation and sustainability of long-term partnerships that support the research process and lead to a field of ancient genomics research that is more sustainable, fair, and inclusive for the regions that have been negatively exploited [20].

6.2. Overlap between Sustainability and Genetic Engineering

Genetic engineering technologies have received a share of scientific research linking them to sustainability. A recent review examined innovations and challenges in crop genetic engineering, particularly CRISPR-Cas, RNA interference, and genetic modification. These technologies have contributed to improving crops that are stress-resistant and tolerant to drought, salinity, heat, and cold. They also improved nutrient use efficiency that enhances nitrogen and phosphorus absorption. Genetic engineering has advanced in pest and disease resistance, which has decreased the need for chemicals and preserved the environment. Innovations offer promising methods for more precise and efficient modifications. Integrating digital technologies like machine learning and big data analytics stimulates trait discovery and improves breeding. Genetic engineering has contributed to modern agriculture by improving crop productivity, resilience, and nutritional quality. Future research should prioritize developing climate-resistant and nutritionally enhanced crops, focusing on biofortification to address global micronutrient deficiencies. Additionally, future research should focus on developing climate-resilient and nutritionally enhanced crops, integrating digital technologies, and promoting sustainable agricultural practices [21].

A role has been found for genetic engineering in preserving and restoring biodiversity. It has been observed that the loss of biodiversity caused by human damage to its surroundings and climate change threatens the resilience of ecosystems globally. Advances in genomic engineering provide an alternative solution by restoring genetic diversity from ancient samples, biobanks, and related species. Lost adaptive traits can be restored, and human immunity against emerging risks such as diseases and climate change can be strengthened. Genomic engineering, when combined with habitat restoration and other traditional conservation measures, can make species more resilient to future environmental changes [22].

Genetic engineering contributes to finding environmental applications for addressing modern problems, including: the genetic modification of specific metabolic enzyme pathways in bacteria, to treat environmental pollutants (toxins, hydrocarbons, heavy metals, and pesticide)s. Environmentally sustainable modification of crops includes providing crops with enhanced and genetically modified traits, such as nitrogen fixation, drought tolerance, and pest resistance, leading to sustainable productivity improvements, reduced resource inputs, and minimized environmental damage. It also enhances the adaptability of certain plant species in degraded ecosystems, to facilitate their reintroduction into areas affected by habitat loss, deforestation, or urban encroachment. It also includes targeting invasive species that threaten biodiversity using developed biological control agents. Protection of endangered species includes cloning, assisted reproduction, and genome modification, new methods for protecting endangered species. These techniques are used to preserve genetic diversity, restore declining species populations, and prevent their extinction. Improving and deploying genetically engineered organisms for environmental applications require strong regulatory frameworks, risk assessment plans, and engagement with stakeholders to ensure safety, transparency, and public acceptance. There is a need for long-term monitoring and an adaptive management approach to evaluate environmental effects and mitigate anticipated risks [23].

Genetic engineering controls environmental biotechnology, as it offers efficiency, accuracy, versatility in uses, sustainability, and innovation. By using engineering techniques, innovative solutions can be found to address pollution, manage waste, produce renewable energy, and preserve the ecosystem. Modified plants improve their abilities to accumulate, metabolize, and remove pollutants, absorbing heavy metals, organic pollutants, and radioactive compounds, reducing costs and providing a sustainable environment. Some microorganisms break down pollutants in the environment, such as hydrocarbons, heavy metals, and pesticides. Engineered microorganisms have been developed that break down plastic waste into non-toxic substances. Plants and other microorganisms capture carbon and reduce emissions of greenhouse gases that are harmful to the climate. These organisms can produce renewable energy [24]. The diagram of this topic is shown in the form (2) below:

6.3. Overlap between Sustainability and Genetic Production

Modern technological innovations have opened many horizons in bioengineering; there is a need to increase investment in new sustainable agricultural technologies to achieve greater resource conservation and better stress tolerance in farms and fields. Genetic engineering offers a wide range of genetically modified organisms, including crops, animals, and microbes. Some genetic engineering applications support increasing the efficiency of resource use in bio-production and enhance the resilience of food systems in handling environmental and human-made risks [25].

The CRISPR-Cas9 has been used in producing sustainable food, as CRISPR-Cas9 technology has emerged as a promising pathway for developing plant genomics and accelerating the domestication of perennial plants. This technology has played a significant role in crop improvement, enhancing various traits such as appearance, yield, and resistance to diseases and environmental stresses. CRISPR-Cas provide an applied and flexible method for improving and controlling genes. Research using this technology has advanced significantly, from understanding genes in understudied species to directly identifying disease-causing genes [26].

There are also used new genomic techniques in organic production, as organic farming involves the use of new food genomic techniques (NGTs), and this provides crop diversity and the production of sustainable, efficient, low-cost food [27].

Genetically modified crops have also been used to produce sustainable and enhanced food, as crop genetic modification techniques such as CRISPR/Cas9 contribute to producing sustainable foods, increasing productivity, generating more benefits than harm, and alleviating the food crisis. The principles of sustainable agriculture include environmental protection, promoting human health, and improving the economy, including eliminating hunger and supporting food security [28].

6.4. Overlap between Sustainability and Green Genetic Technologies

Green genetic technologies involve the use of genetically engineered organisms to find diverse sustainable solutions with improved quality and productivity, by reducing environmental damage, lowering costs, saving time, and increasing efficiency and accuracy. Green technologies integrate biotechnology and agriculture, represented by the production of genetically improved plants. These technologies produce crops that are resistant to drought, environmental conditions, and pests, and create environmentally friendly pesticide alternatives through genetic selection of desired traits. Green technologies integrate artificial intelligence and genetic modification of crops to create sustainable smart ecosystems [29].

Green technologies, contributing to processes of prediction, prevention, mitigation, adaptation, and restoration. genetically engineered crops enhance food production and tolerate drought and salinity. The second area is fuels and chemicals: carbon pathway enzymes are identified, and genetically engineered microbes are used to fix nitrogen instead of chemical fertilizers and remove pollutants, in addition to harnessing photosynthesis in the field of renewable energy instead of traditional fuel sources. The other area is ecosystem modification: genetically modified organisms are used to improve carbon dioxide and methane absorption, reduce temperatures, and decrease methane, nitrous oxide, and greenhouse gas emissions. Molecular interactions are also modeled computationally to predict and address environmental changes [30].

Other study examined the effect of preservation methods on the productivity and integrity of nucleic acids from African yam bean. It aimed to improve cost-effective preservation methods for storing African yam bean leaf tissues to ensure the extraction of high-quality DNA. Its leaves were subjected to a variety of preservation conditions, including chemically stored solutions (1× CTAB, 1× TAE, and 70% ethanol) and temperature settings (-20°C, 4°C, 25°C, and above 25°C). DNA preserved using cetyltrimethylammonium bromide solution and Tris-acetate-EDTA solution showed lower stability and increased contamination over time. The results showed that freezing at -20°C is the most effective method for preserving African yam bean leaf tissues in terms of DNA yield and purity, as it consistently produces DNA suitable for molecular applications. The preservation method using ethanol also showed excellent performance, providing a feasible and cost-effective alternative for resource-limited environments. In contrast, preservation methods using CTAB and TAE solutions showed limitations, with DNA stability declining over time. The study recommended testing these methods on other underutilized and degradation-resistant species to verify their effectiveness. It also recommended conducting further studies on the interactions between plant metabolites and preservatives to improve DNA yield and purity [31].

Green extraction techniques have been used as an advanced approach for sample preparation. A review aimed to update some of the Green Extraction Techniques (GreET) that have been developed and applied in the biological, food, and environmental fields. Methods to enhance and accelerate extraction efficiency while reducing solvent consumption include sorbent-based techniques such as solid-phase microextraction (SPME) and fabric phase sorptive extraction (FPSE), solvent-based techniques (μQuEChERS; micro, quick, easy, cheap, effective, robust, and safe), ultrasound-assisted extraction (UAE), microwave-assisted extraction (MAE), in addition to supercritical fluid extraction (SFE) and pressurized solvent extraction (PSE). Most GreET require small sample amounts, very low or no solvent amounts at all, and simple, fast, and easy-to-use systems that can be easily automated. SPME and its various formats are particularly effective in this field because they often require minimal preliminary sample preparation and can be easily coupled to analytical instruments, providing enhanced extraction capability and simultaneous measurement of different compounds with general sensitivity. The use of GreET also reduces the risk of analytical degradation and matrix changes resulting from enzymatic conversion, in addition to rapid sample collection and cleanup. Finally, the technology is miniaturizable, allowing its application in small living systems, storage and transport of samples, and easy connection to portable devices. The FPSE is a very promising GreET device and has a major advantage compared to other microextraction methods, as it allows direct analysis extraction without modifying the sample. Food samples: the rapid transition from solvent-based extraction and solid-phase extraction to miniaturized forms has significantly reduced solvent consumption. Being simpler, faster, more economical, and easier to use than CET techniques, SPE techniques have become more popular. In turn, this has promoted continuous improvement of innovative techniques that respect the principles of green analytical chemistry. Future research should be directed towards innovative sorbents/nanomaterials capable of enhancing retention efficiency, loading capacity, and selectivity. The use of artificial intelligence to enhance the automation of extraction and the use of alternative reagents will also be notable [32].

Molecular biology has been harnessed to accelerate green recovery, as the study of the complexities of life holds great potential to develop new biology-based solutions to the challenges of climate change, biodiversity loss, biochemical flows, and pollution caused by industry, including prevention, adaptation, and mitigation. A study was conducted to highlight some areas that could offer potential solutions to urgent global challenges. Other research fields will require further research and the development of new techniques and may provide solutions in the long term. The study includes finding the optimal research ecosystem and funding mechanisms to support interdisciplinary collaboration, appropriate ethical and legal frameworks, and training for future scientists. Establishing suitable types of partnerships will be pivotal for achieving effective research and innovations to harness molecular life sciences in the green recovery [33].

A comprehensive review was conducted on the green synthesis of nanoparticles. Future research directions were proposed to overcome health and environmental challenges, including improving synthesis protocols, in-depth mechanical studies, and developing more robust and reproducible techniques. Finally, the importance of the transformative potential of green-manufactured nanoparticles in addressing global health and environmental challenges was emphasized [34]. The green genetic technologies application is shown in the figure (3) below:

6.5. Overlap between Sustainability and Environmental Genetics

There are effective techniques for preserving biodiversity, as environmental DNA (eDNA) technology has the potential to become an important tool for biodiversity research and the conservation of aquatic ecosystems. eDNA analysis has been used in studies aimed at detecting specific target species using PCR and qPCR tests, as well as in community-level (i.e., multi-species) studies using gene subtyping. eDNA plays a big role in detecting rare or endangered species, invasive species, environmental and community diversity of ecosystems, functional diversity, wildlife, and conservation science [35].

RNA interference technology and biological control have been combined to protect the environment and promote global food security and agricultural biodiversity. A recent study also called for merging environmentally friendly biological control practices with the use of RNA interference (RNAi)-based pesticide technology, which shows high precision in targeting specific genes through the mechanism of double-stranded RNA (dsRNA) designed for specific RNA sequences. This specificity makes dsRNA a biologically safe candidate for inclusion in global conservation initiatives. This view is supported by the Earth BioGenome Project, a valuable effort to advance RNAi technology due to its benefit in providing full genome sequences, which allows for identifying genetic targets in crop pests and potentially related sequences in non-target organisms. There is a need for multidisciplinary studies that combine enhanced biological control techniques with RNAi technology [36].

7. Obstacles in Applying Genetic Technologies

Experts have identified several limits that hinder or reduce the efficiency of genetic technologies. It has been noted that the main obstacle to the wider adoption of molecular technologies is the high cost of their requirements. There are also several limitations with older technologies that have led to gaps and a lack of full understanding of the genome, including off-target activity, low homology-directed repair efficiency, delivery of Cas components in organisms, and immune responses. The short reads produced by most current platforms significantly limit our ability to accurately describe large repetitive regions and structural variations, leaving large parts of the genome unknown [14].

The study by [24], also highlighted a set of challenges and considerations in applying genetic engineering in environmental biotechnology, particularly regarding environmental impacts; genetically engineered organisms can have harmful environmental consequences, such as unintended gene flow, disruption of ecosystems, or unintended harm to non-target organisms. Another challenge is related to regulatory control; releasing genetically engineered organisms and products into the environment requires strong regulations to anticipate and address risks to human health, ecosystems, and biodiversity. The third obstacle has to do with society's perceptions; genetic engineering technologies raise ethical, social, and security concerns in society's view, which means careful communication, community involvement, and decision-maker participation are needed. Another obstacle is the long-term effects; the long-term impacts of genetically modified organisms on environmental sustainability, ecosystem interactions, and genetic diversity require comprehensive monitoring, risk studies, and adaptive plans. There are unforeseen consequences; unexpected consequences arise from applying genetic engineering in environmental technology, which calls for ongoing oversight and research.

Other researchers have also pointed out that the adoption of genetically modified crops is influenced by various social and economic factors, including public perceptions, regulatory frameworks, and intellectual property rights. By balancing innovation with ethical standards, genetic engineering can play an important role in addressing global food security challenges and environmental sustainability, leading to a more sustainable agriculture for future generations. There are still ethical concerns related to biosafety, labeling, and consumer choice, which thorough risk assessments [21].

8. FUTUROLOGY FOR THE DEVELOPMENT OF GENETIC TECHNOLOGIES

Many researchers have touched on futurology for developing genetic technologies. A study by [14], revealed a set of future visions regarding the evolution of genetic technologies, pointing out a global need to develop new techniques, as well as more methods to facilitate molecular analysis in monitoring different diseases, and to develop more efficient ways to track DNA, making comprehensive genomic testing for patients easier and cheaper. It also noted that there are three main factors that will drive the field's development: more research comparing the performance of different techniques in biology, wider use of reporting standards (such as the Minimum Information for Quantitative Real-Time PCR Experiments - MIQE - which describes experiment conditions), and increased participation of researchers from the Global South. There is a need for advancement in these technologies to fill the technical gaps, better understand genetics, and accelerate the discovery of genetic disease causes. Multidisciplinary collaboration between biologists, engineers, and technicians can lead to newer and better ways to meet present and future needs. This requires technological advancement or the creation of new, superior methods to combat deadly diseases with minimal harm. Since high-throughput automated technologies provide very large amounts of data, this calls for greater collaboration among researchers in experimental labs to make it easier and achieve the best scientific results.

Ralph Rapley, (2021) [16], found that there is a growing trend towards automating manual processes to provide a high level of reliability. The process can be automated using a low-throughput QIAcube system. Several nucleic acid extraction machines are used in an automated way, like the QIAsymphony system, now in places that require high productivity, such as disease diagnostic labs, and it operates computer-controlled and robotically, taking about 45 minutes without any manual involvement.

Another study mentioned that advances in nucleic acid research will open the door to new diagnostic techniques, personalized medicine, and innovative nanodevices. The importance of designing highly specific antisense oligonucleotides (ASOs) will provide personalized therapeutic technologies, tailored to each patient, which could lead to more effective and efficient medical interventions. Overcoming challenges related to nucleic acid delivery, improving the safety and effectiveness of treatments, and developing nucleic acid-based technologies will be crucial for the effective contribution of nucleic acids in medicine, biotechnology, and beyond. Through collaborative efforts, multidisciplinary approaches, and ongoing technological developments, the future of nucleic acid research looks promising, offering great opportunities for scientific progress and improving human health [17].

Future research should also focus on developing crops that are resistant to climate change and have improved nutritional value, integrated digital technologies, and sustainable practices [21].

Table 1: Applications of genetics techniques

No.	Genetics technique	Application	Study
1	direct-to-consumer (DTC) testing	Analysis of genetic diseases, and we may carry ID cards that include our genomic characteristics	[12]
2	Sequencing	Nucleic acids identification	[14]
3	Genetic modification (e. g. CRISPR-Cas9)	Understanding nucleic acids and genes (diseases, such as hereditary blindness, and viral infections)	
4	affinity chromatography	Denaturation and the extraction of nucleic acids	[16]
5	Gel electrophoresis	Separate DNA molecules	
6	HPLC	DNA mutations	
7	10xChromium technique	Single-cell DNA analysis (single-cell gene expression)	
8	Mapping and staining	Detect mRNA sequences and quantities	
9	PCR (RT-PCR)	Amplify RNA and microorganisms' diagnosis	
10	RAPD	Pathological diagnosis	
11	STS	Genomic mapping	
12	Retrospective studies	Ancient DNA analysis	
13	Next-generation sequencing	Detect sequences of large numbers of DNA fragments at the same time	
14	Single-molecule seq. RT	Serves field studies when laboratory work is difficult,	
15	Microarrays	methylation, genome-wide association, mutations, mRNA levels, polymorphisms, transcription levels	
16	HapMap project	Analyzing inherited SNPs in bulk	
17	PCR	Amplify a small amount of DNA from a complex mixture of raw material, and pathological analyses	[14, 16]
18	Oligodeoxynucleotide nucleotides (ODNs)	Biomarker identification, understanding biological systems and disease	[17]
19	Highly specific antisense oligonucleotides (ASOs)	Precisely targeting individual genetic variations or accurately identifying disease biomarkers	

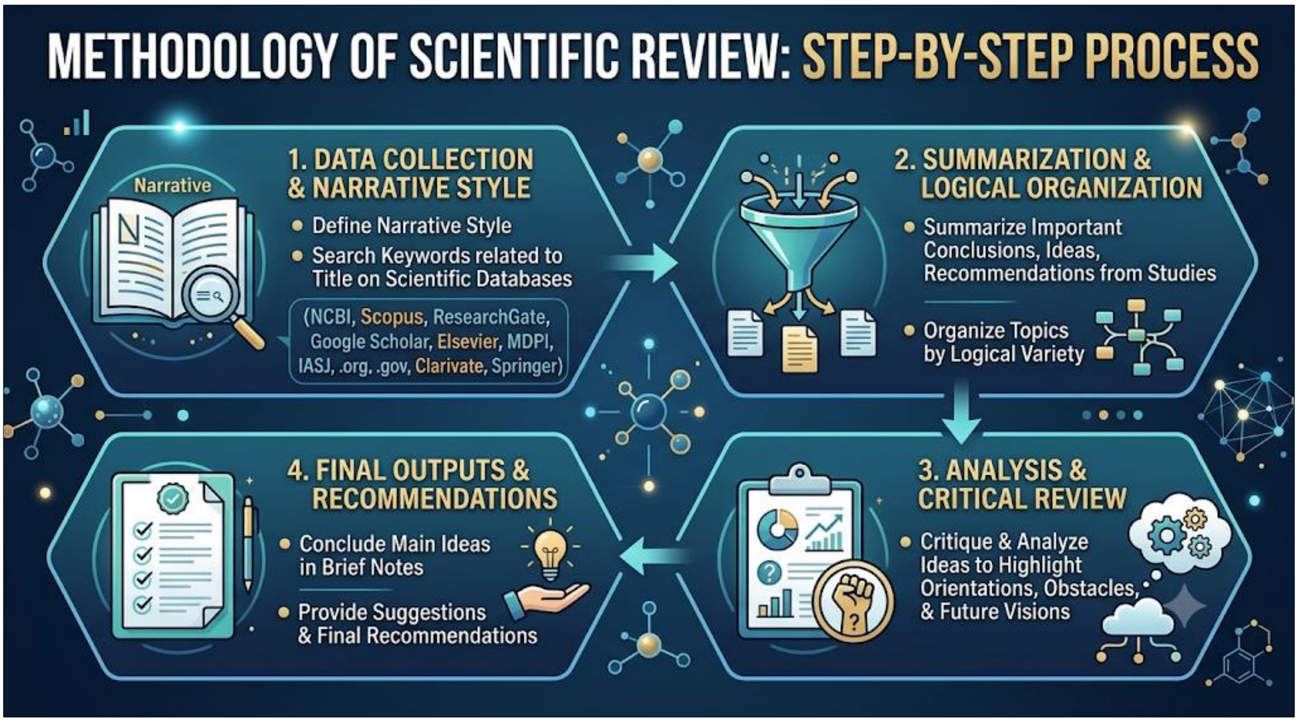


Figure 1: The steps of the current study performance

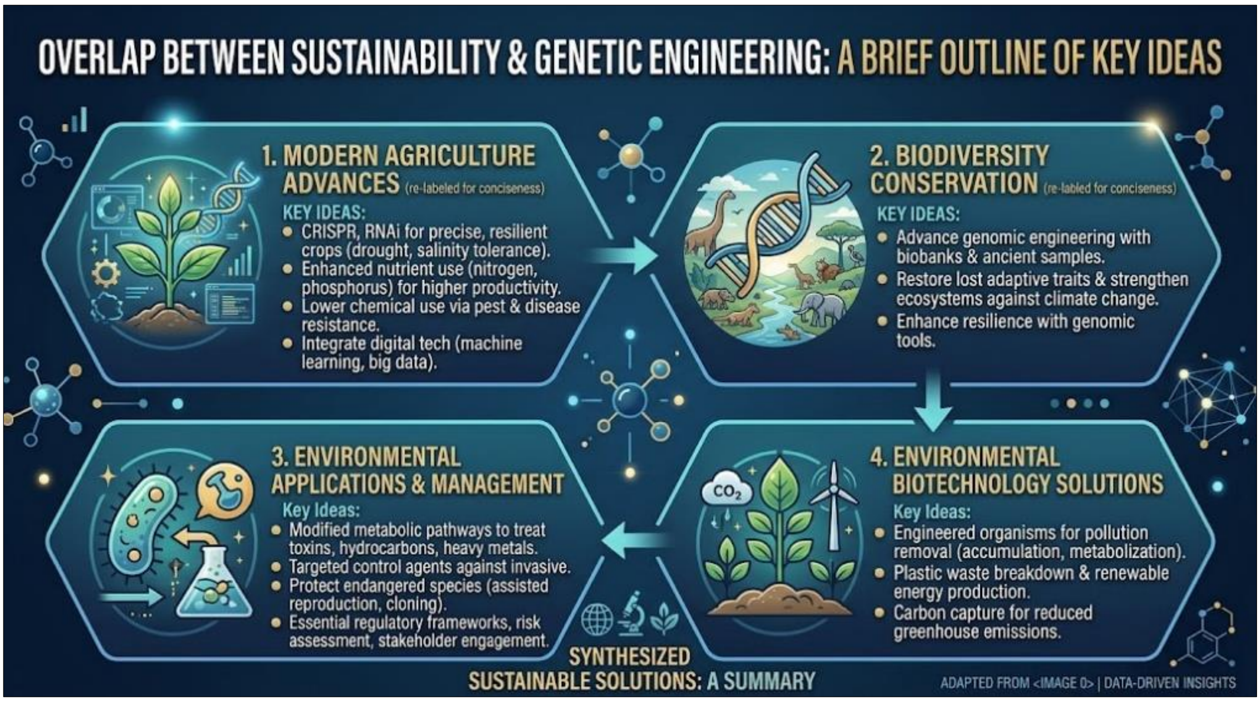


Figure 2: Overlap between Sustainability and Genetic Engineering

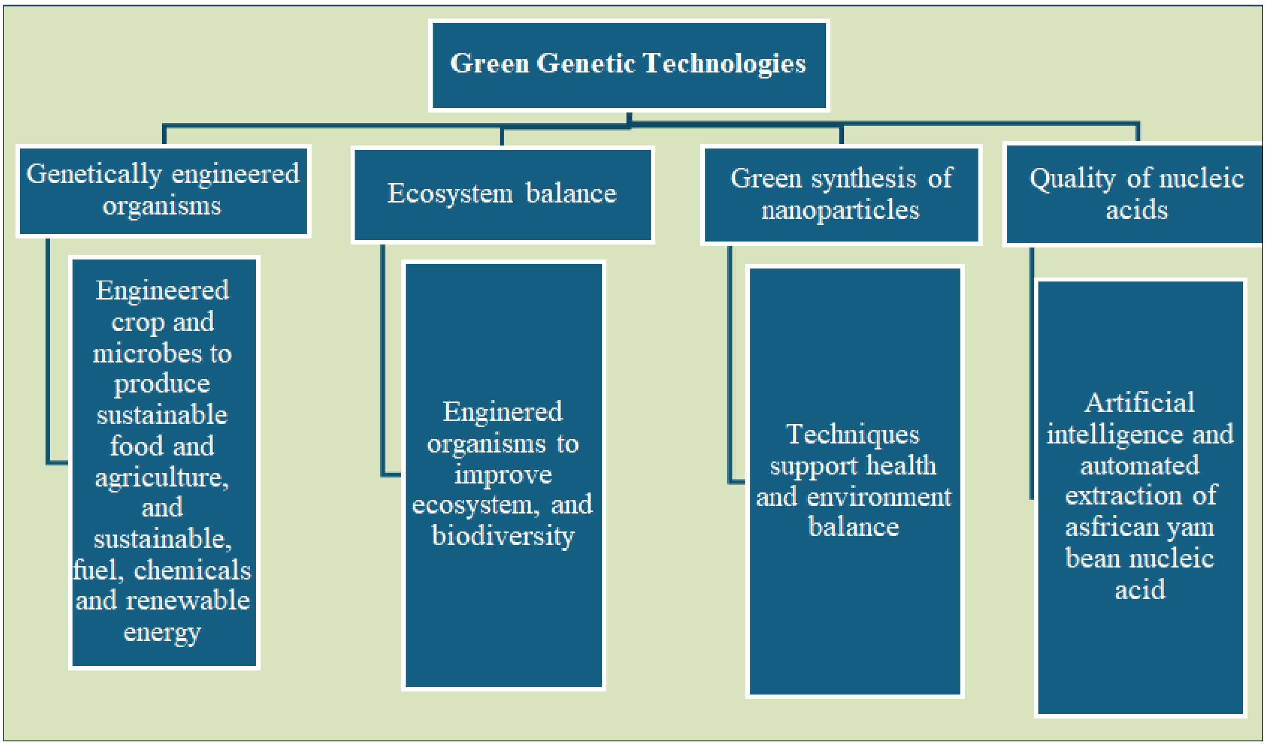


Figure 3: Diagram of Green genetic technologies

9. CONCLUSION

After collecting, reviewing, and analyzing previous studies, a strong overlap observed between sustainability and genetic technologies. Sustainable genetic technologies included three main areas: the first is the field of sustainable extraction and preservation of nucleic acids; sustainability aims to extract nucleic acids in the best, fastest, easiest, and most cost-effective way. Freezing African yam leaves at -20°C provides the best efficiency, purity, and lowest cost. Also, repeated freeze-thaw cycles of viral double-stranded DNA negatively affect its extraction efficiency, while using VTN without serum improves sample quality, test sensitivity, and detection using qRT-PCR techniques. Furthermore, the study of ancient DNA is needed for the sustainability of genomic research and global collaboration. Additionally, genetic diversity is restored from old samples and biobanks are provided. The second field is sustainable genetic engineering techniques (engineered organisms); they enhance efficiency, accuracy, diversity, predictability, prevention, and adaptation, while reducing time, cost, and damage. Genetically engineered organisms, genetic selection techniques, and CRISPR-Cas technology also improve the quality of medical care, food abundance, environmental quality, disease control, poverty reduction, economic strengthening, and crop resistance to stress, drought, salinity, heat, and cold to face climate change. They also improve the absorption of nitrogen and phosphorus, uptake of organic pollutants and radioactive materials, and resistance to pests and diseases. Engineered organisms also boost sustainable biological and food production, help in pollution treatment, protect endangered species, and produce renewable energy. Hydrocarbons, heavy metals, pesticides, plastics, and carbon are disposed of sustainably, nitrogen is fixed, fuel and chemicals are produced, and high heat is managed. Environmental DNA is also used to detect rare, endangered, or invasive species using PCR. The third area is computational modeling, digitization, automation, artificial intelligence, robotics, and big data related to genetic technologies; it helps in trait discovery, plan improvement, and providing sustainable smart ecosystems. Studies have also revealed several obstacles to improving and sustaining genetic technologies, including high costs, off-target activity, immune responses, difficulty accurately describing large genetic repeats, and the harmful environmental from gene flow. They also include social fears regarding genetic engineering applications. Previous studies have also highlighted several future insights for creating sustainable genetic techniques; it is expected to make disease monitoring and diagnosis easier through computer and robotic means, increase the efficiency, productivity, reliability, and automation of techniques, reducing its time, harm, and costs by comparing the performance of various techniques.

10. Recommendations and Suggestions

The current study recommended conducting future research to uncover the overlap of each branch of genetic technologies with sustainable development, and to enhance applied research for sustainable development of various genetic technologies by comparing efficiency, effort, time, cost, and harm among different genetic technologies used for the same purpose. It also recommended supporting innovations, entrepreneurial projects, and patents in the field of sustainable genetic technologies.

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13. Conflicts of Interest: The authors declare no conflict of interest.

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